Long-range beam-beam interactions in RHIC

Wolfram Fischer, BNL

T. Sen, FNAL, J. Qiang, LBNL

U. Dorda, J.-P. Koutchouk, F. Zimmermann, CERN

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2. Some simulation results
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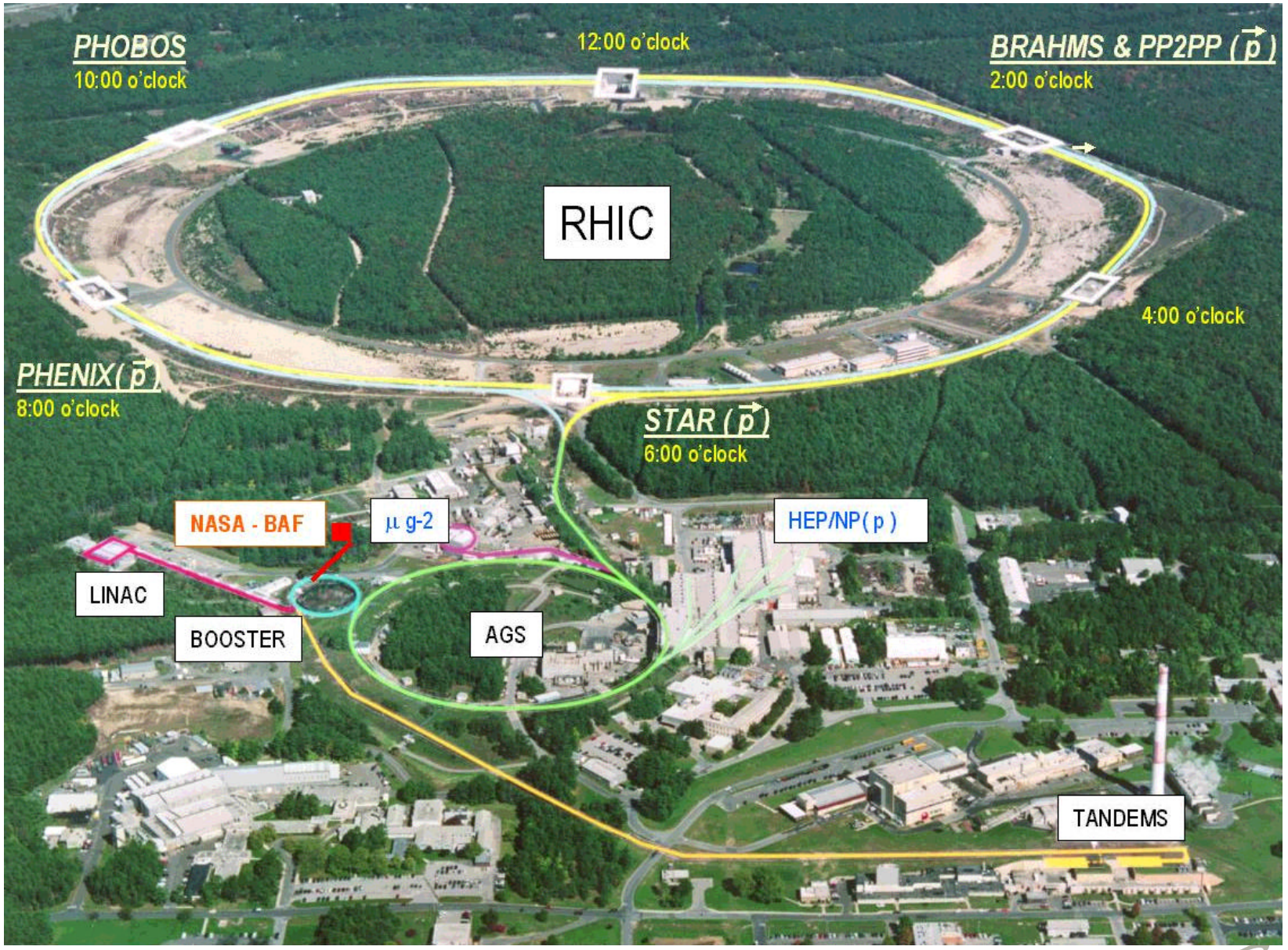
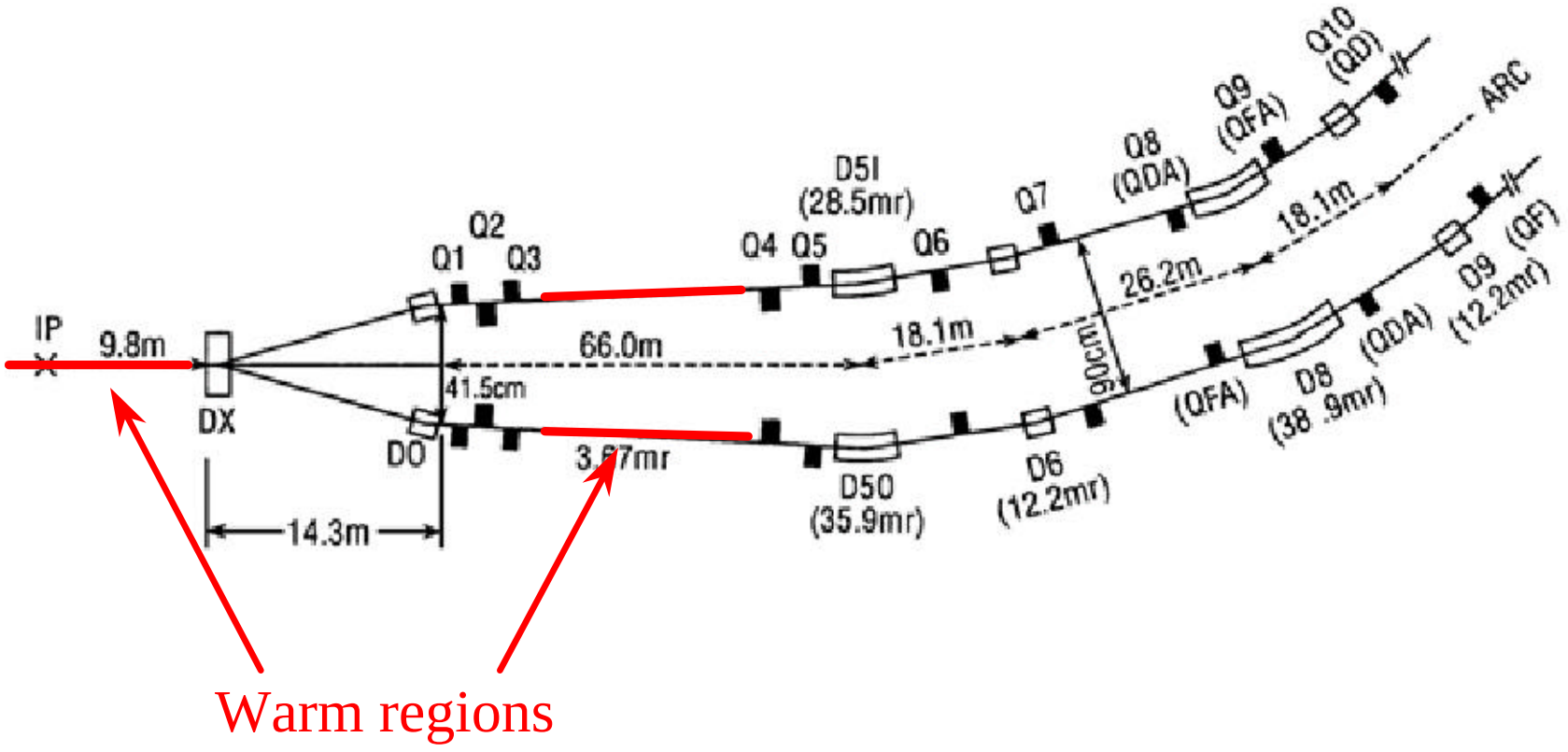
RHIC overview

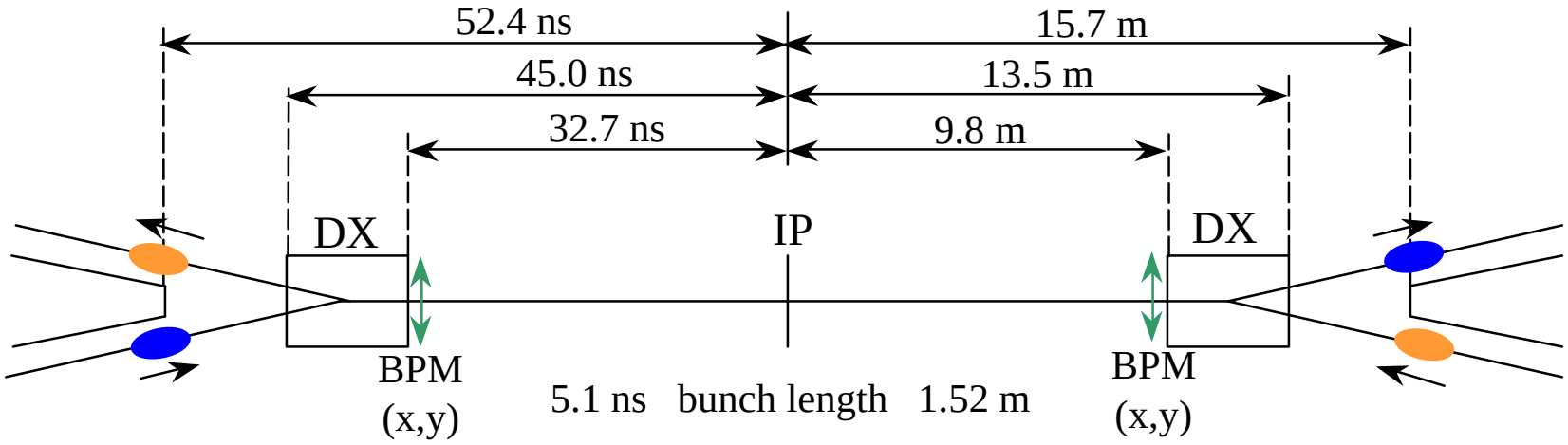


RHIC Interaction Region (I)



RHIC Interaction Region (II)

Bunch length and spacing for rf storage system (2520 buckets), 120 bunches (only 60 bunches in 2001)



RHIC long-range beam-beam scans 2005

Observation of beam lifetime as function of

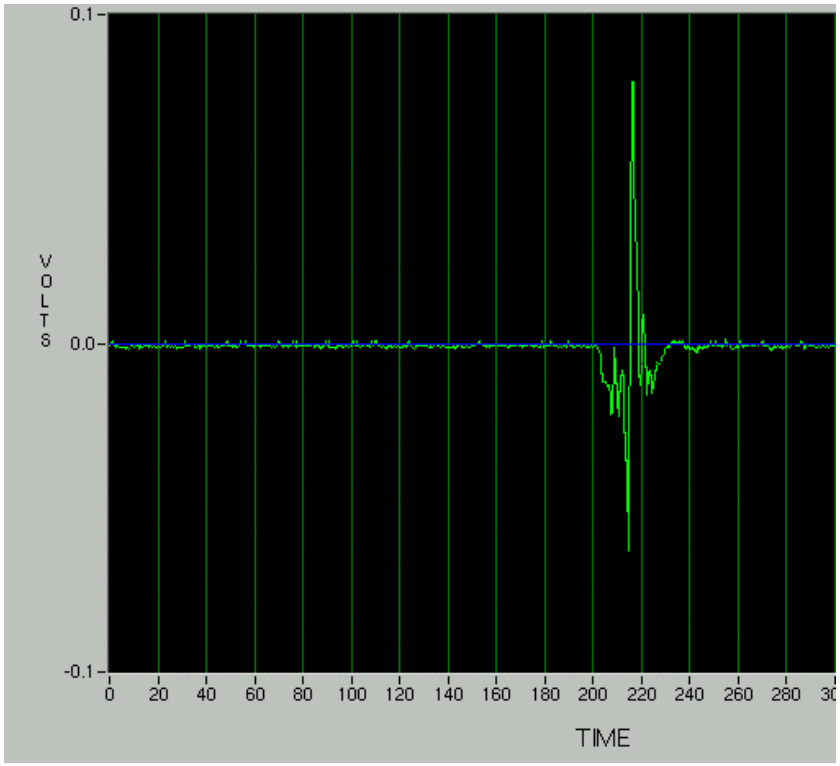
- **Transverse tunes**
- **Vertical separation**

Quantity	Unit	value
Proton energy E	GeV	24.3
Bunches per beam N	…	1
Bunch intensity N_b	10^{11}	1-2
Norm. emittances ε_x, ε_y (95%)	mm.mrad	20, 13
Long-range interaction location	m from IP	0.0, 10.6
Transverse tunes (Q_x,Q_y)	…	B(.733,.722) Y (.727,.723) B(.735,.722) Y(.728,.723) B(.738,.725) Y(.727,.722) B(.739,.727) Y(.726,.739)
Vertical separation	mm	10 – 0
	σ	11 – 0

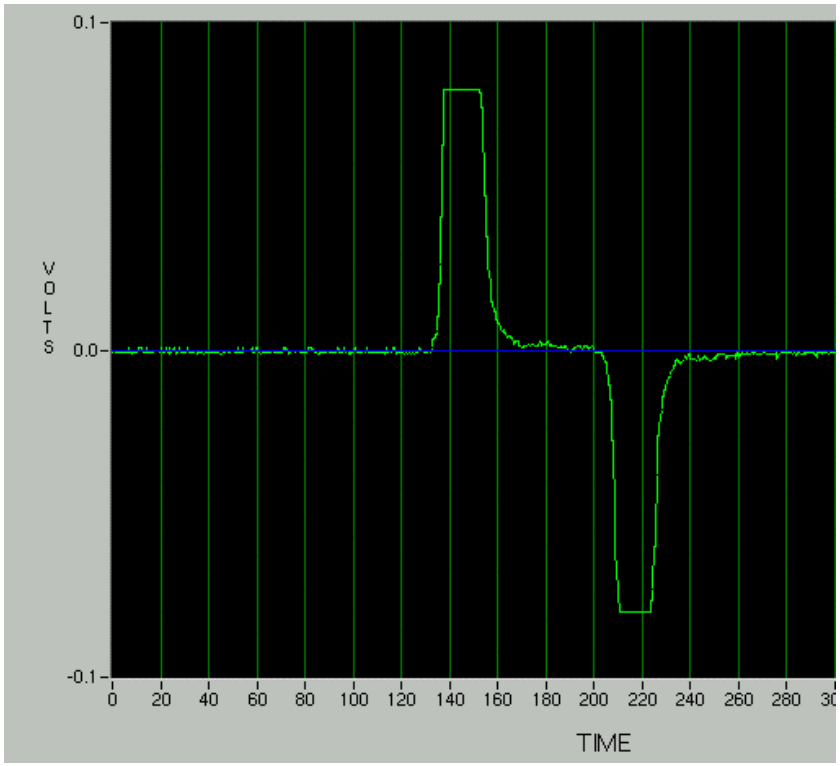
RHIC experiment – control of interaction location

Wall current monitor at IP4 (sees both beams)

Interaction at nominal IP

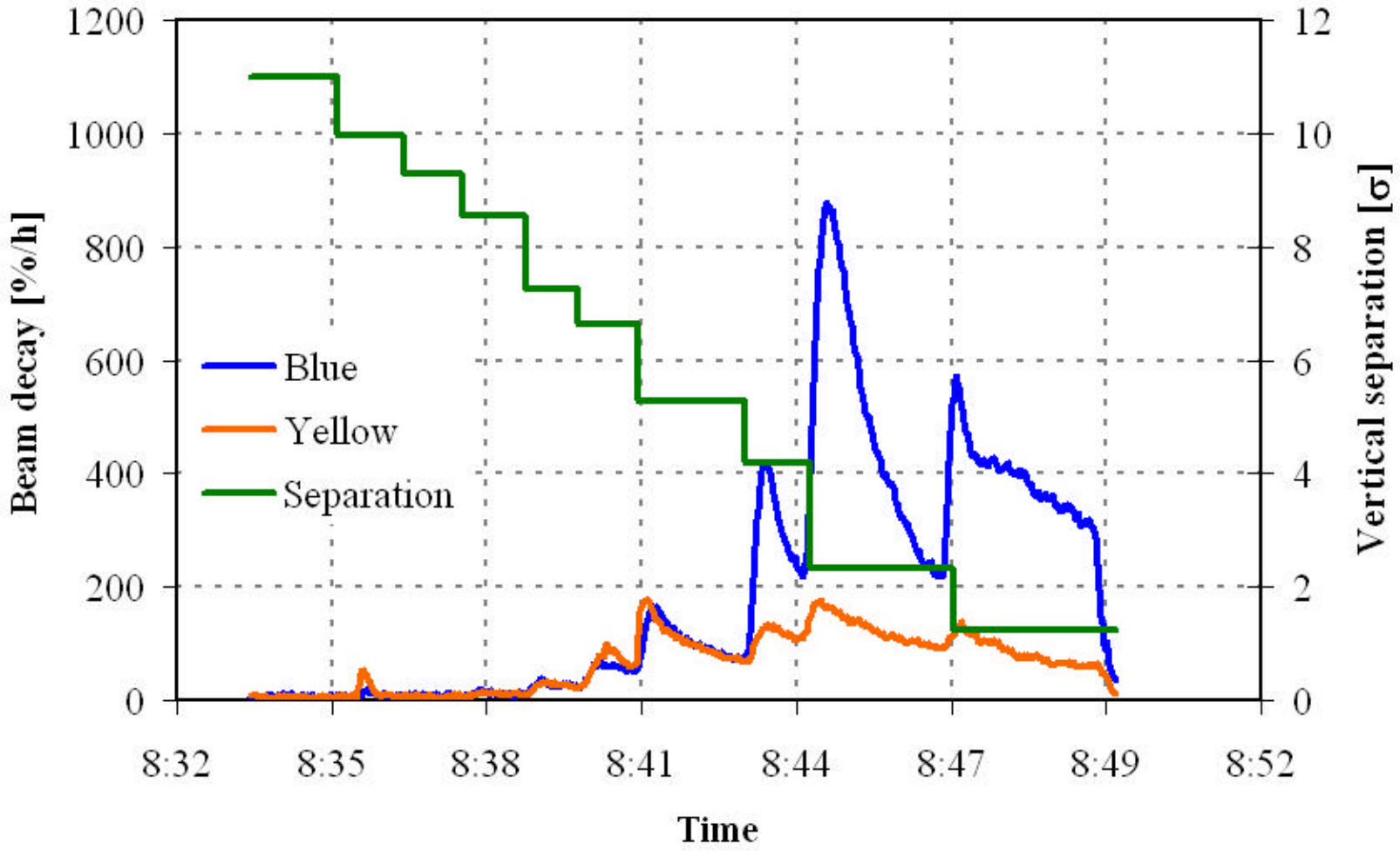


Interaction moved by 10m



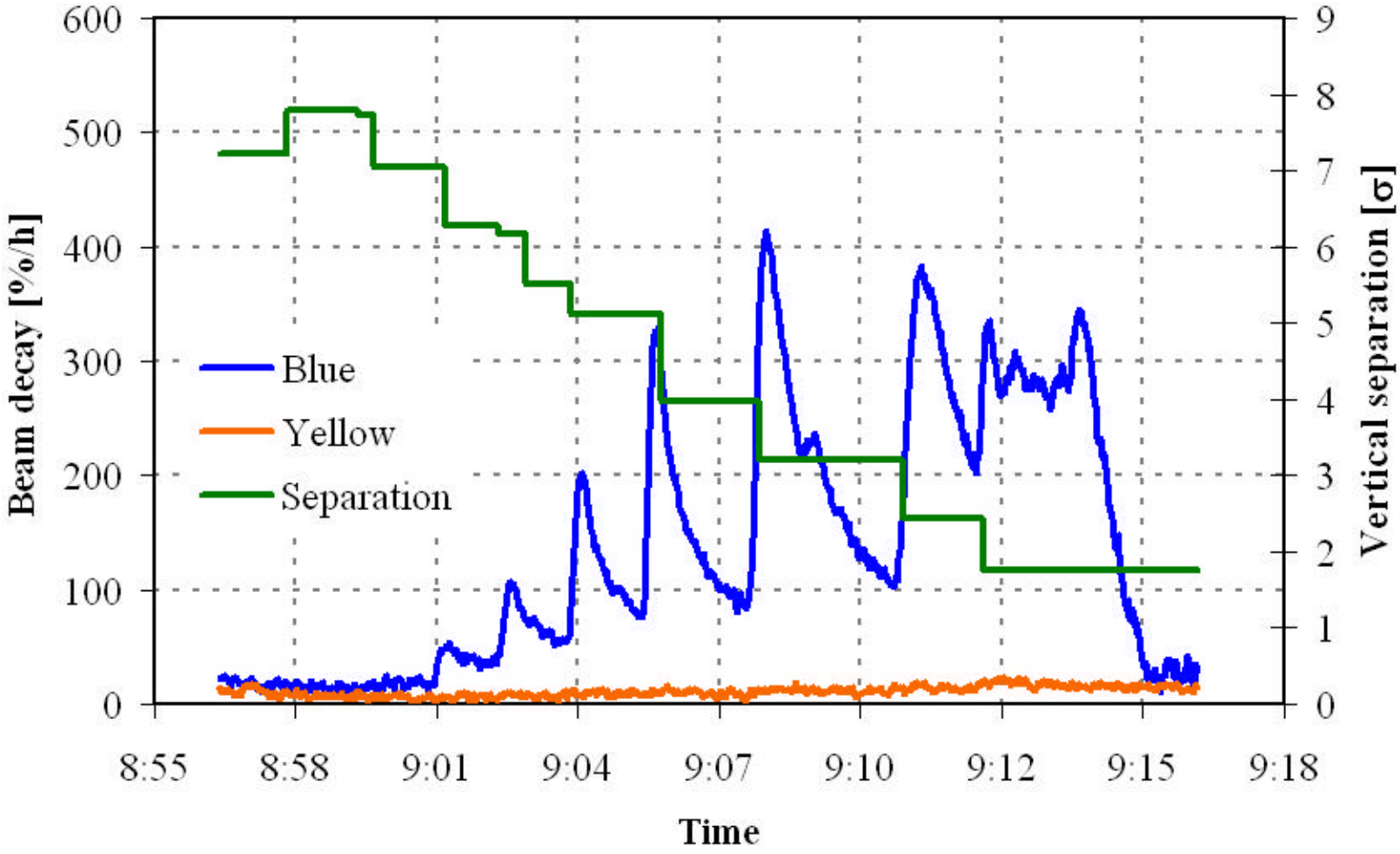
Experiment – scan 1

Collision at s = 0 m, Blue beam moved vertically
Tunes B (0.733,0.722) Y (0.727,0.723)



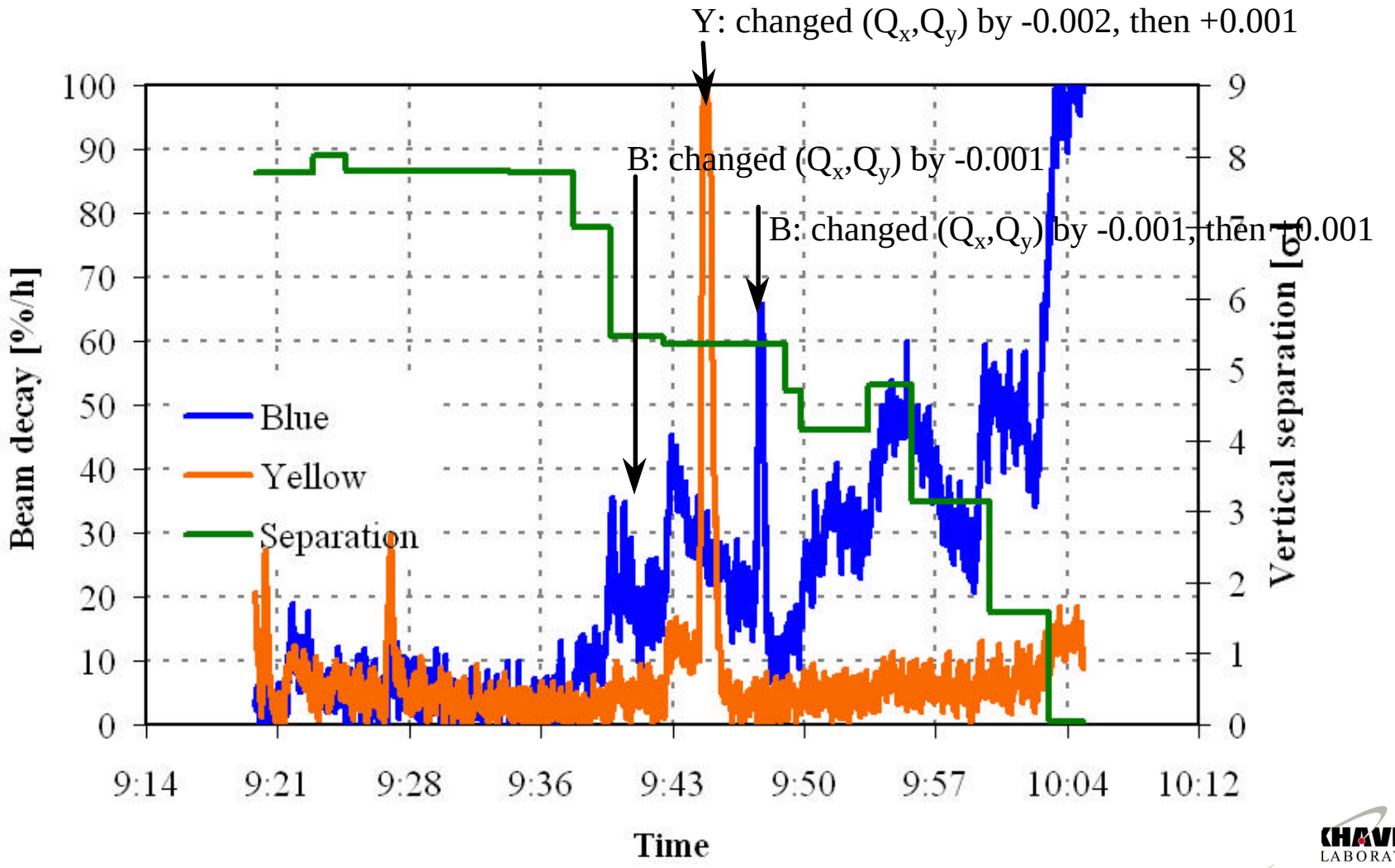
Experiment – scan 2

Collision at s = 10.6 m, Blue beam moved vertically
Tunes B (0.735,0.722) Y (0.728,0.723)



Experiment – scan 3

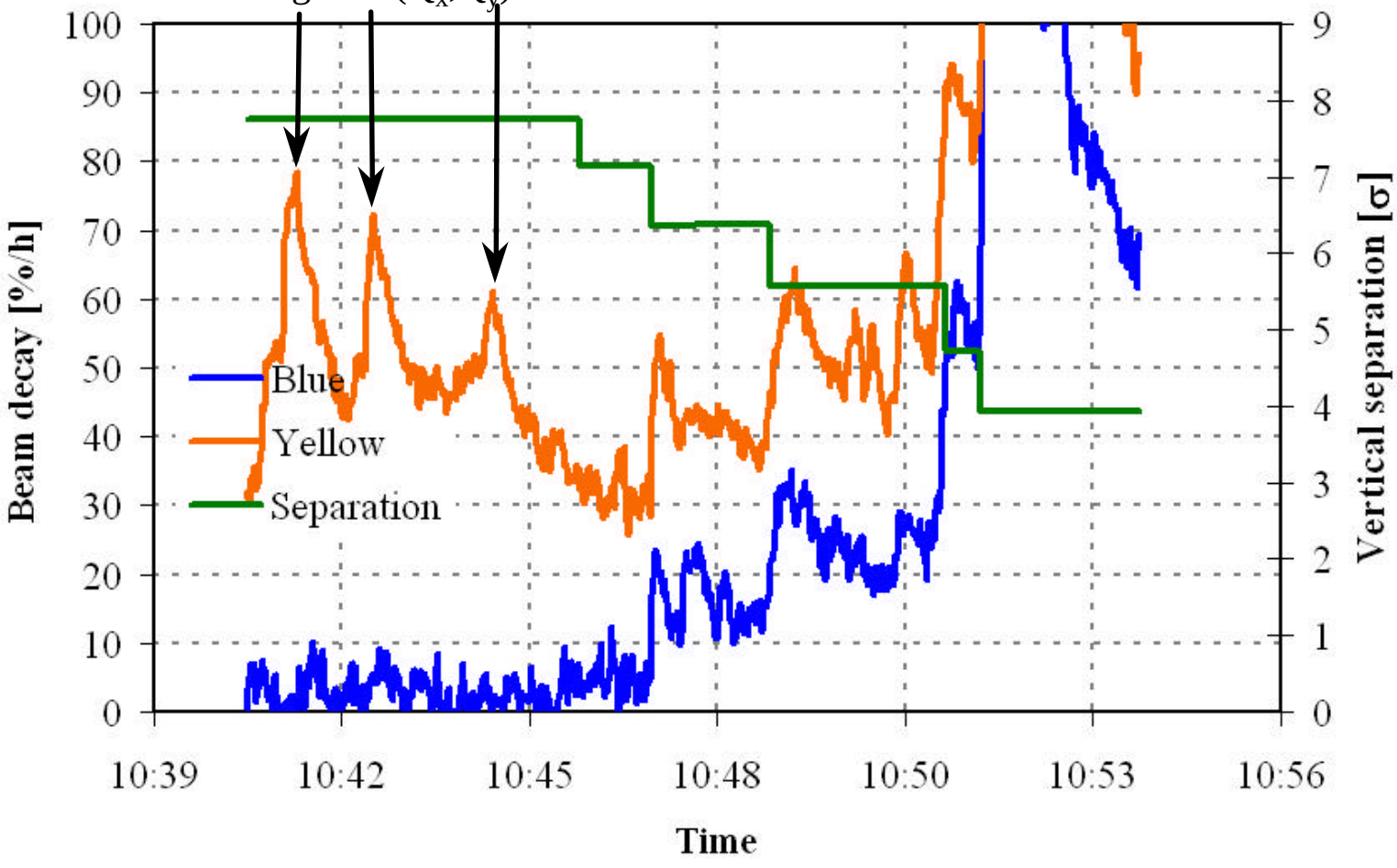
Collision at s = 10.6 m, Yellow beam moved vertically
Tunes B (0.738,0.725) Y (0.727,0.722)



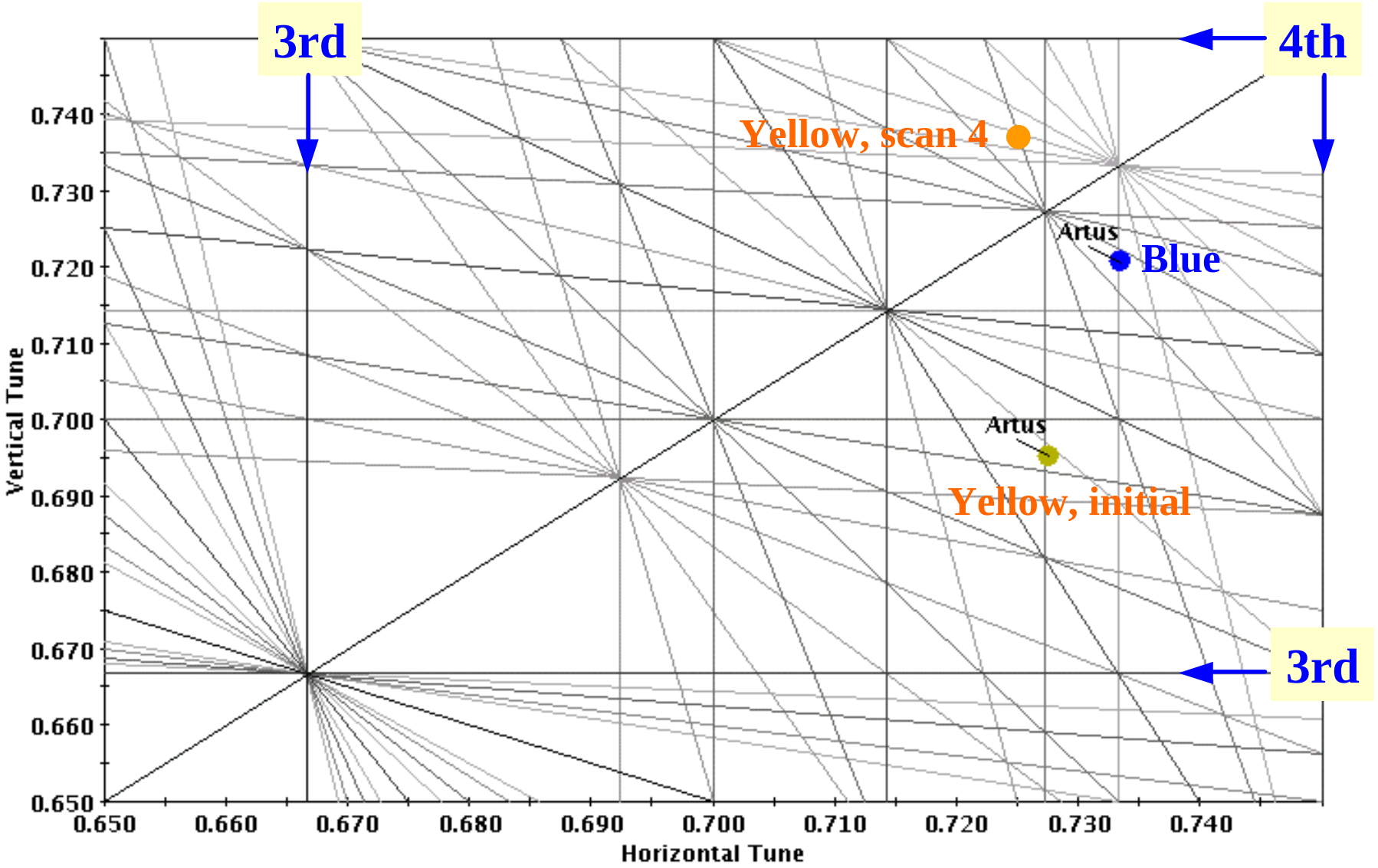
Experiment – scan 4

Collision at s = 10.6 m, Blue beam moved vertically
Tunes B (0.739,0.727) Y (0.727,0.738)

Y: attempt to improve lifetime,
small changes in (Q_x,Q_y)



Experiment – tune diagram



RHIC experiment

- Did not correct tunes and orbits for each new separation change
- Beam lifetime clearly dependent on vertical separation
- Found strong tune dependence of lifetime,
  ruled out tune change due to orbit change as dominating effect
- With mirrored tunes beam lifetime of both beam comparable

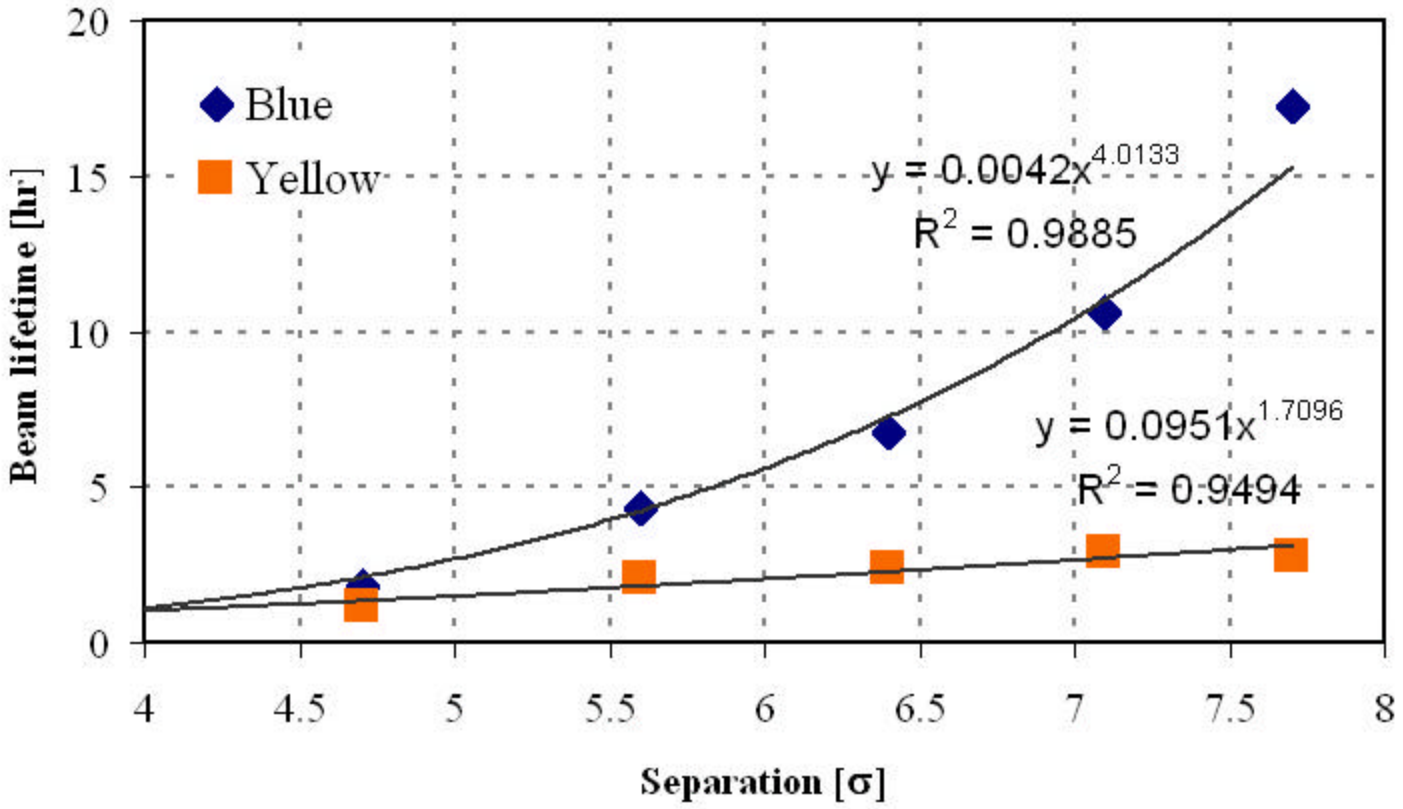
Effects of long-range beam-beam interaction observable at RHIC injection with a single bunch.

Lifetime versus separation

SPS : $\tau \approx 5\text{ms}\ (d/\sigma)^5$ [measured 11/09/04]

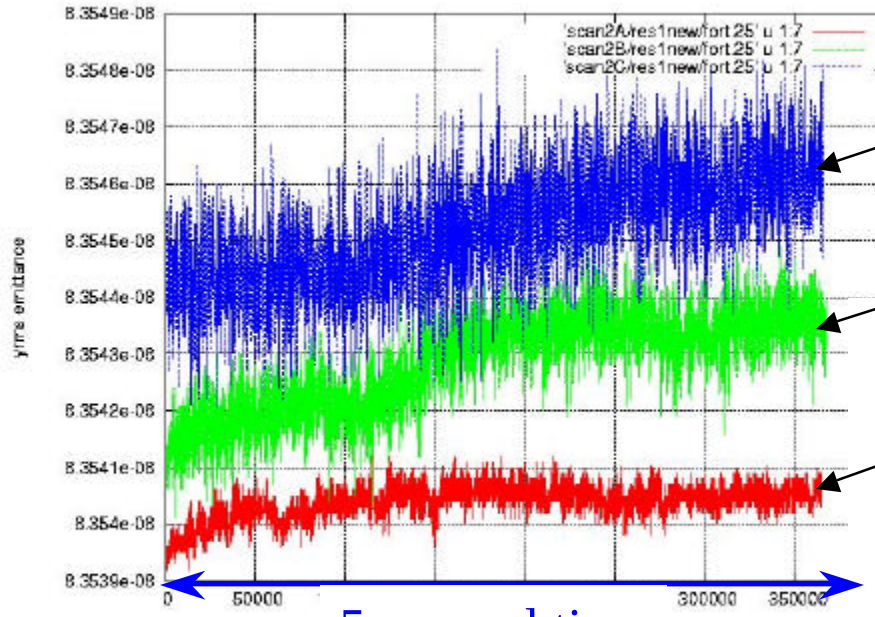
Tevatron: $\tau \sim d^3$ [reported in F. Zimmermann, LTC 11/24/04]

RHIC : $\tau \sim d^4$ or d^2 [measured 04/28/05, scan 4]



Simulation – Ji Qiang, LBNL

Scan 2 – rms emittance vs. time



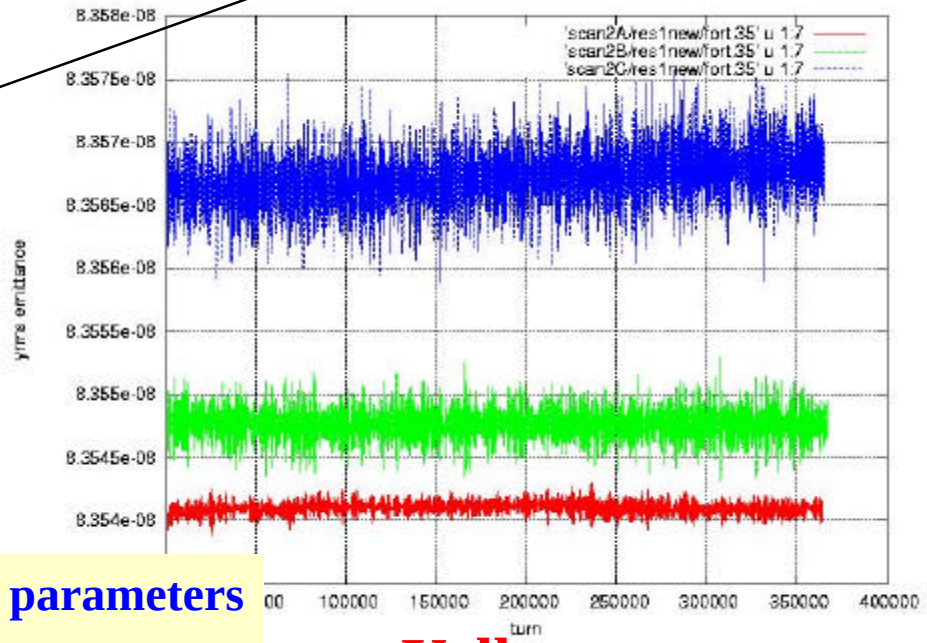
5 sec real time

Blue

4.7σ separation

5.54σ

7.1σ



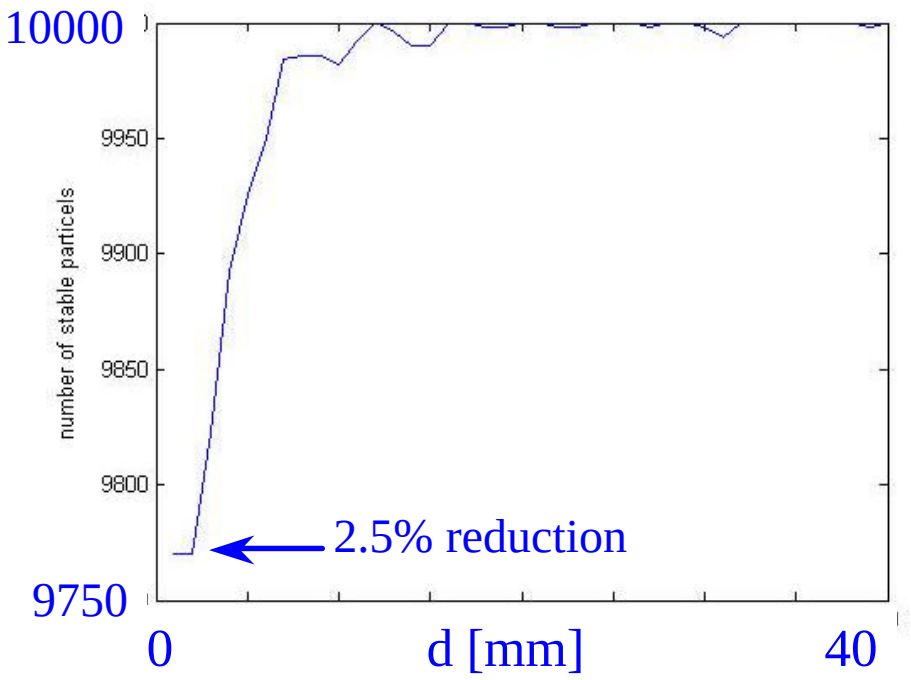
Yellow

Difference between beams visible for scan 2 parameters
Little effect seen for scan 4 parameters

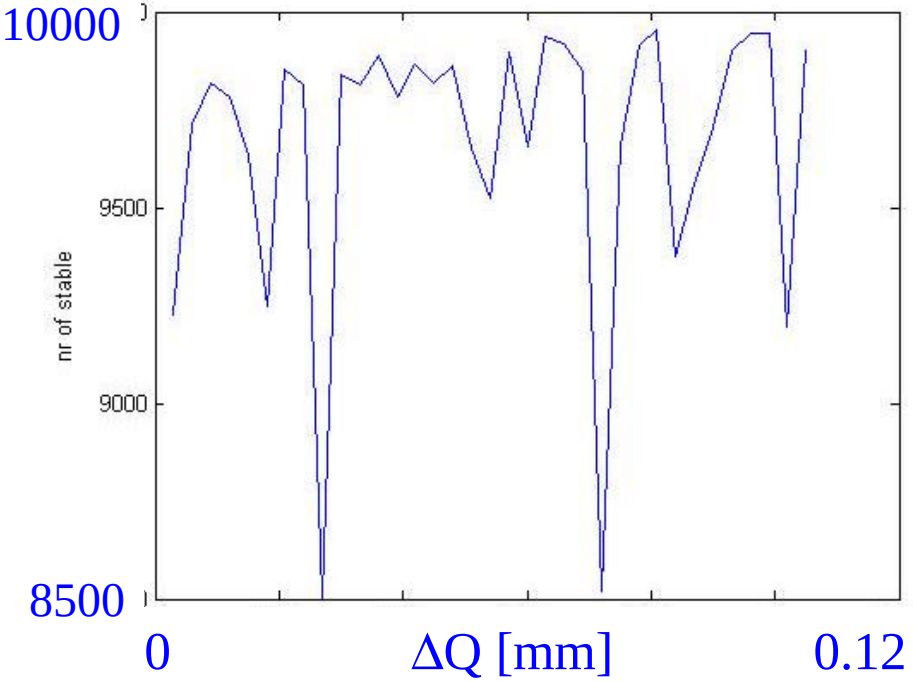
Simulation – Ulrich Dorda, CERN

Scan 1 parameters for Blue, 4 sec real time

No of stable particles vs. distance

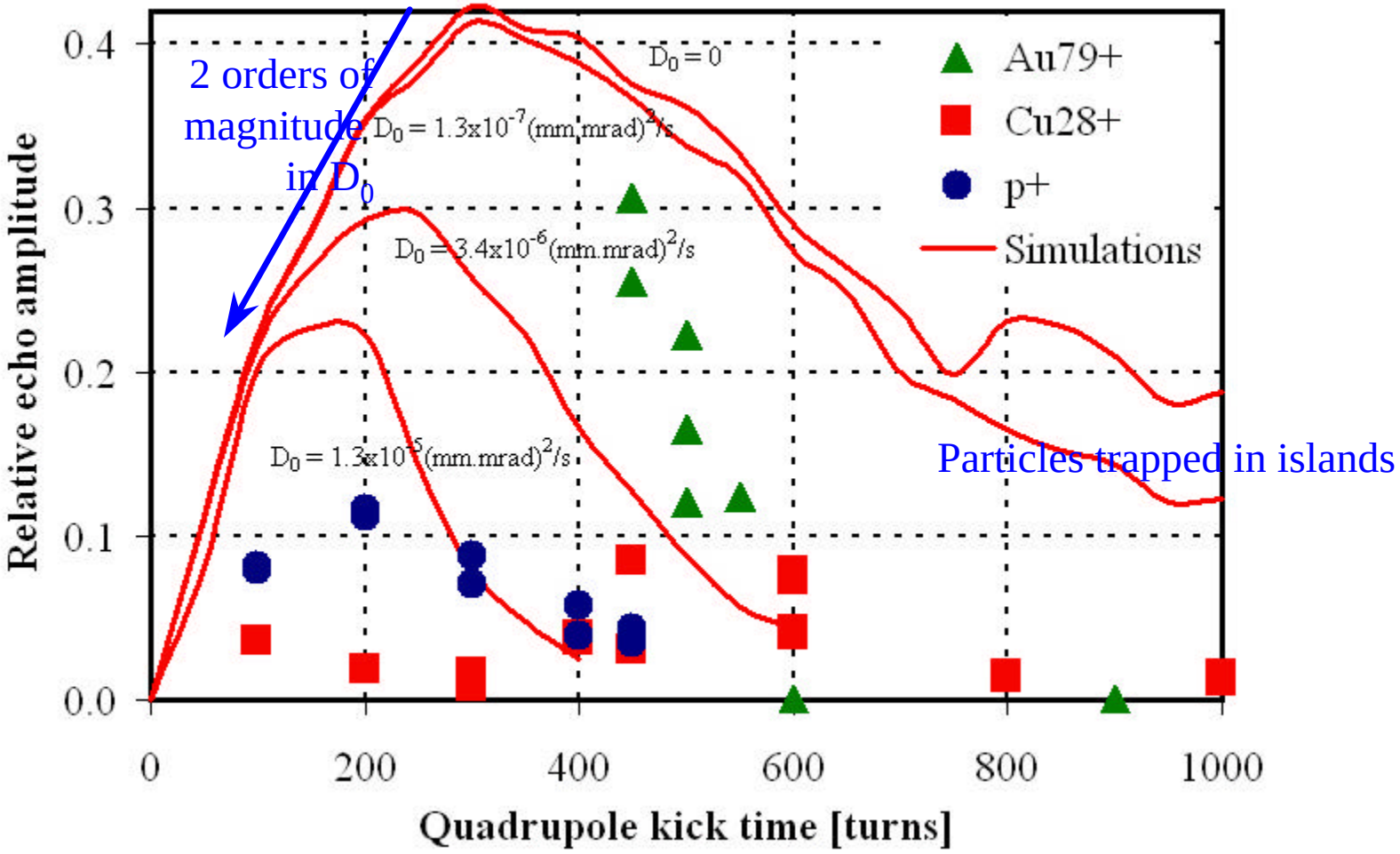


No of stable particles vs. tune



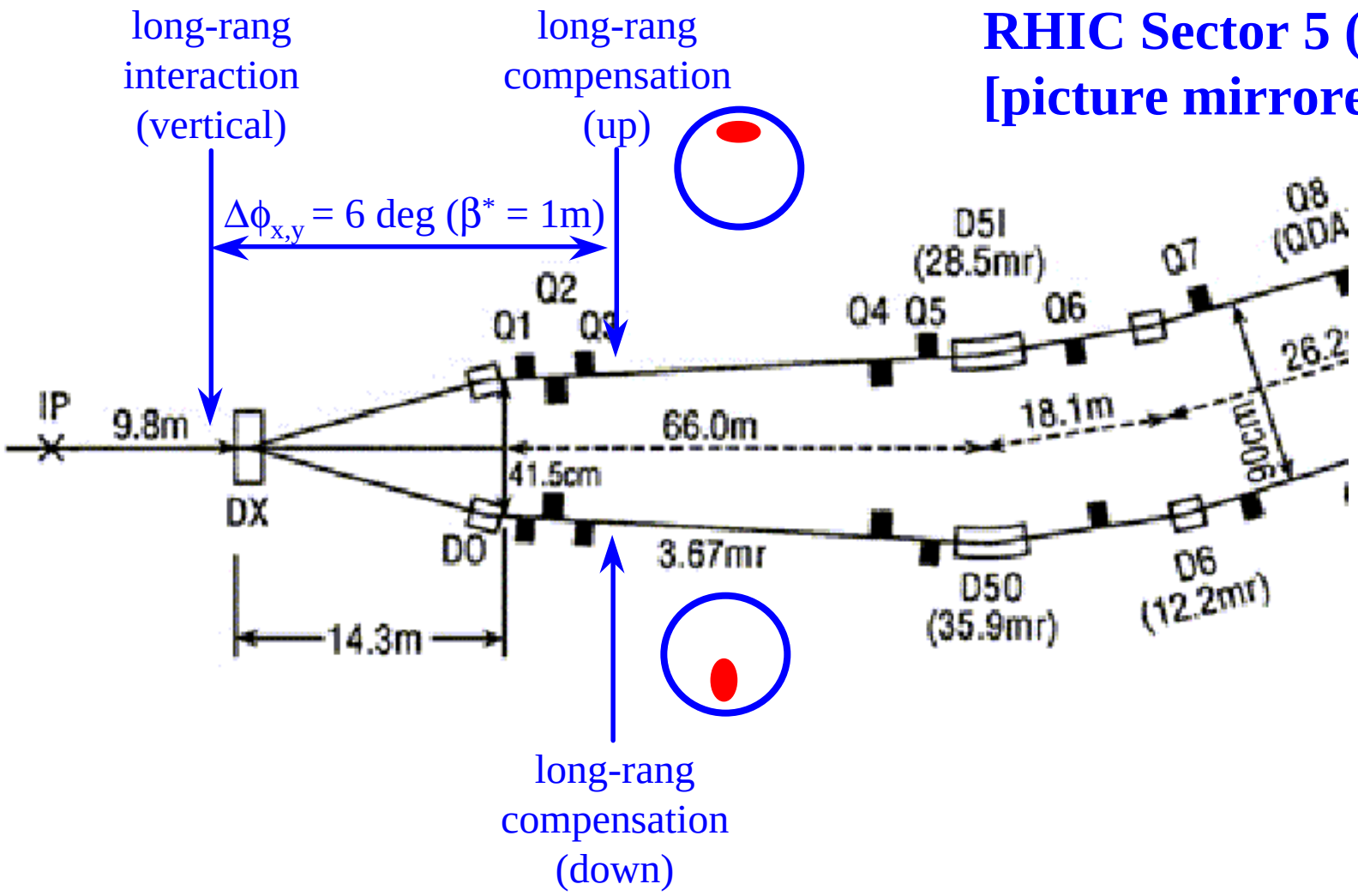
Code: BBTRACK (weak-strong, multi-particle, bb is the only nonlinearity)

Simulations – are we missing something?

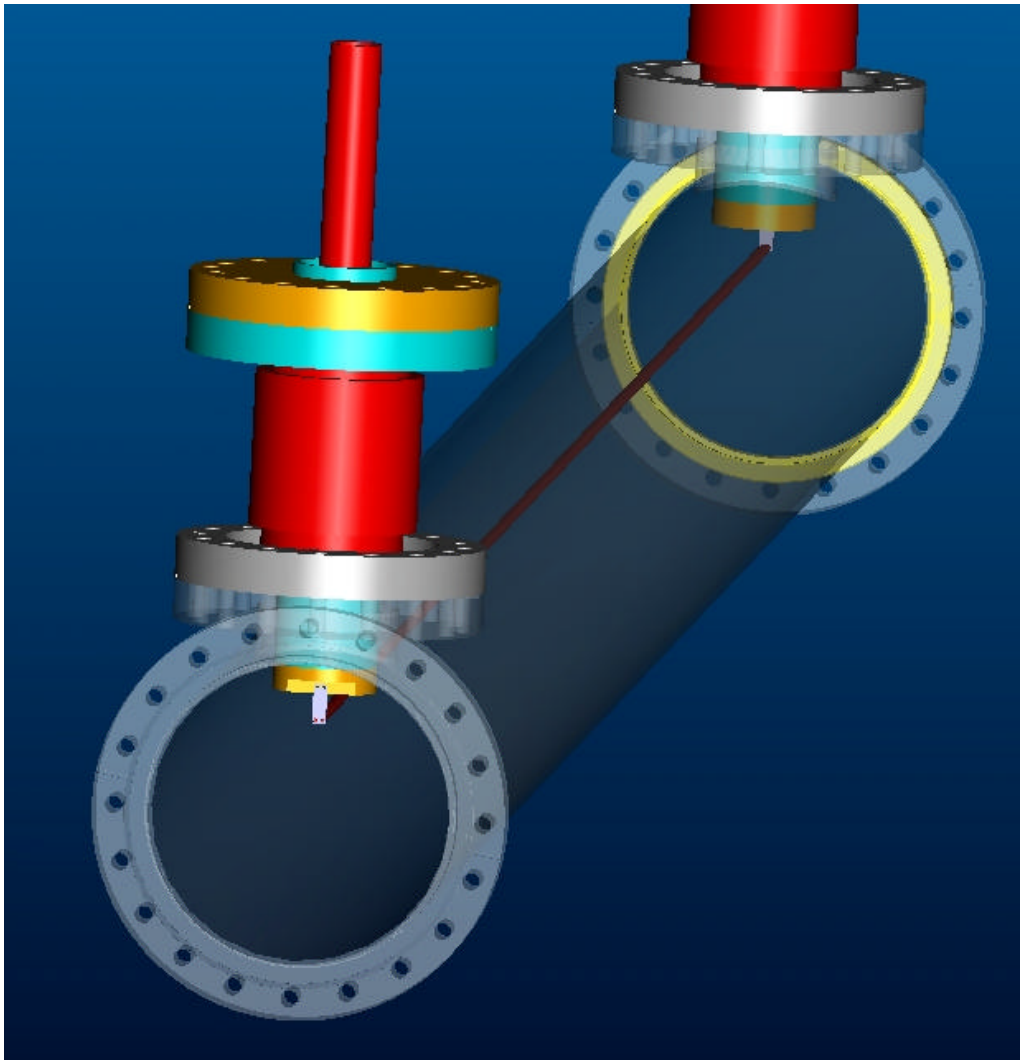


Transverse echoes measurements show stronger diffusion for protons than for heavier ions (without BB)

RHIC BBLR design – locations



RHIC BBLR design – drawing



please comment

Main features:

- elliptic copper bar (a/b = 59%)
- air cooled heat sinks
- on vertically movable stand (60mm movement)

RHIC BBLR design – parameters

Integrated strength per long-range collision	Am	9.6
Integrated strength of compensator *IL*	Am	125
Length of wire *L*	m	1.5
Major half axis of elliptic bus bar *a*	mm	4.0
Minor half axis of elliptic bus bar *b*	mm	2.4
Output parameters		
Current in wire *I*	A	83
Electric resistance *R*	mΩ	0.87
Voltage *U*	mV	72.8
Electric power *P*	W	6.1
Max temperature change ΔT_{max}	K	100
Change in length due to ΔT	mm	1.7

~10x single bunch

please comment

RHIC BBLR – DC PS

Power supply specifications:

please comment

- $\Delta I/I \leq 10^{-4}$
- no requirement on long-term I stability (%/hr ok)
- PS with controllable set point
- Inductance in series (12S12 sextupoles) to reduce ripple

RHIC BBLR – AC PS

[2nd draft of Specifications and Requirements for a Pulsed BBLR in LHC and SPS]

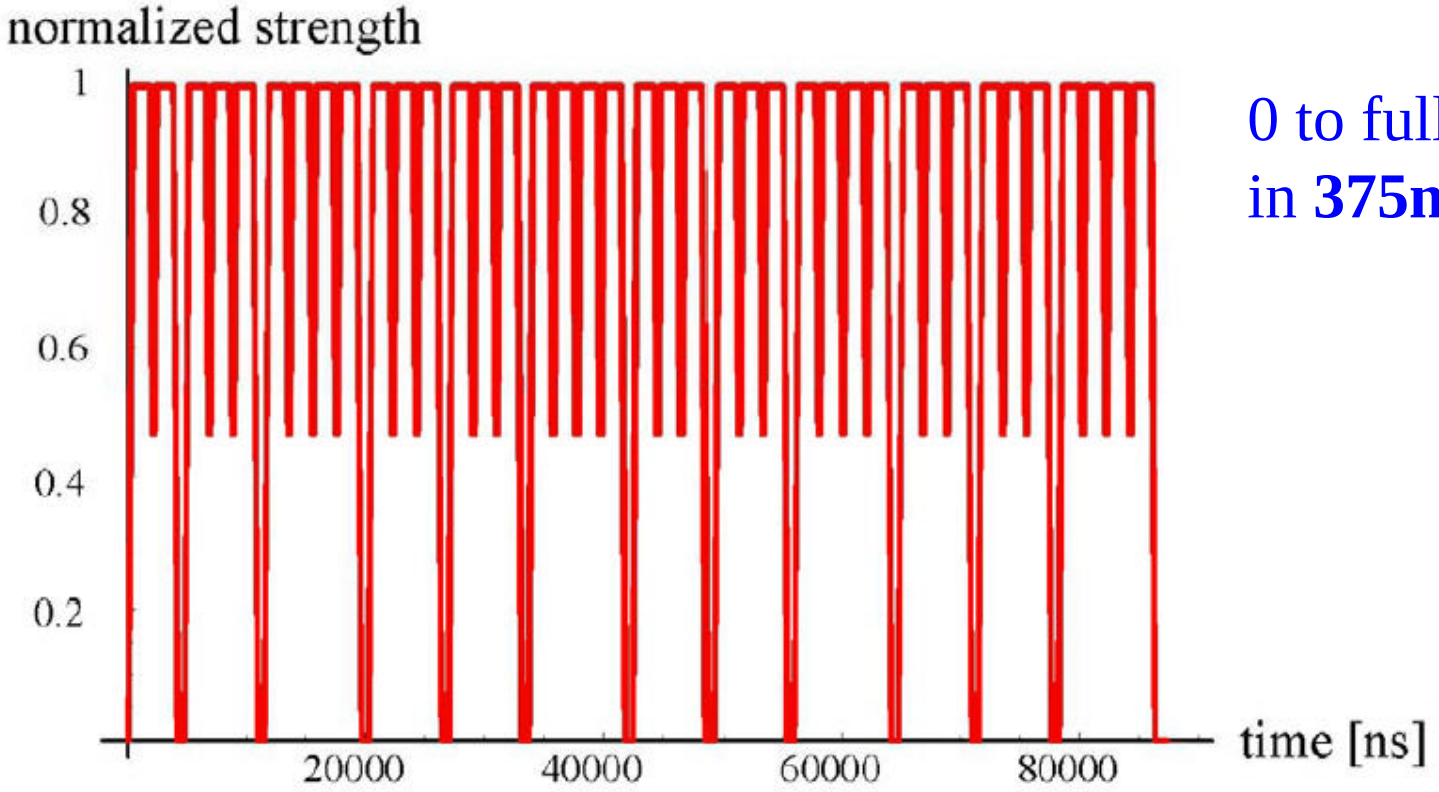


Fig. 2: Pulse pattern of a BBLR in LHC, normalized to a maximum strength of 1. One full revolution period is shown, after which the above pattern repeats.

0 to full strength
in **375ns (~700kHz)**

please comment

What would be an equivalent test in RHIC?

RHIC experimental program proposal

- (d,Q_y) scan at 100 GeV
- Single and multiple long-range interactions

Run-6 (2006) w/o BBLR (ask for 2x3hrs)

Run-7 (2007) with 1 or 2 dc BBLR

Run-8 (2008) with ac BBLR

RHIC BBLR

Possible schedule:

By May ‘06: long-range experiments without compensator (RHIC Run-6)

By May ‘06: design and manufacturing of compensator

By Oct ‘06: compensator installation and testing

By May ’07: long-range experiments with compensator (RHIC Run-7)

By May ’07: design and manufacturing of pulsed PS

By Oct ’08: installation and testing of pulsed PS

By May ’08: long-range experiments with pulsed compensator (RHIC Run-8)

Summary

1. In RHIC, beam loss rate at injection varies sufficiently with vertical separation
   → measurable long-range beam-beam effect
2. Some features were reproduced in simulation
   → still need to improve qualitative agreement
   → quantitative comparison desirable
3. Progress in compensator design for RHIC
   → basic parameter range established
   → basic mechanical and electrical design done
4. RHIC study plan evolving